

ARCNL “Source” update

Oscar O. Versolato for EUV Plasma Processes
and EUV Generation & Imaging groups
Advanced Research Center for Nanolithography



ARCNL

The Advanced Research Center for Nanolithography (ARCNL)

MISSION

The research of ARCNL focuses on the **fundamental physics** that is involved in or related to current and future technologies that are or will be employed in the context of lithography and nanolithography, primarily for the semiconductor industry.

PARTNERS

Foundation for Fundamental Research on Matter (FOM/NWO), University of Amsterdam, VU University Amsterdam, ASML

LOCATION

Amsterdam Science Park

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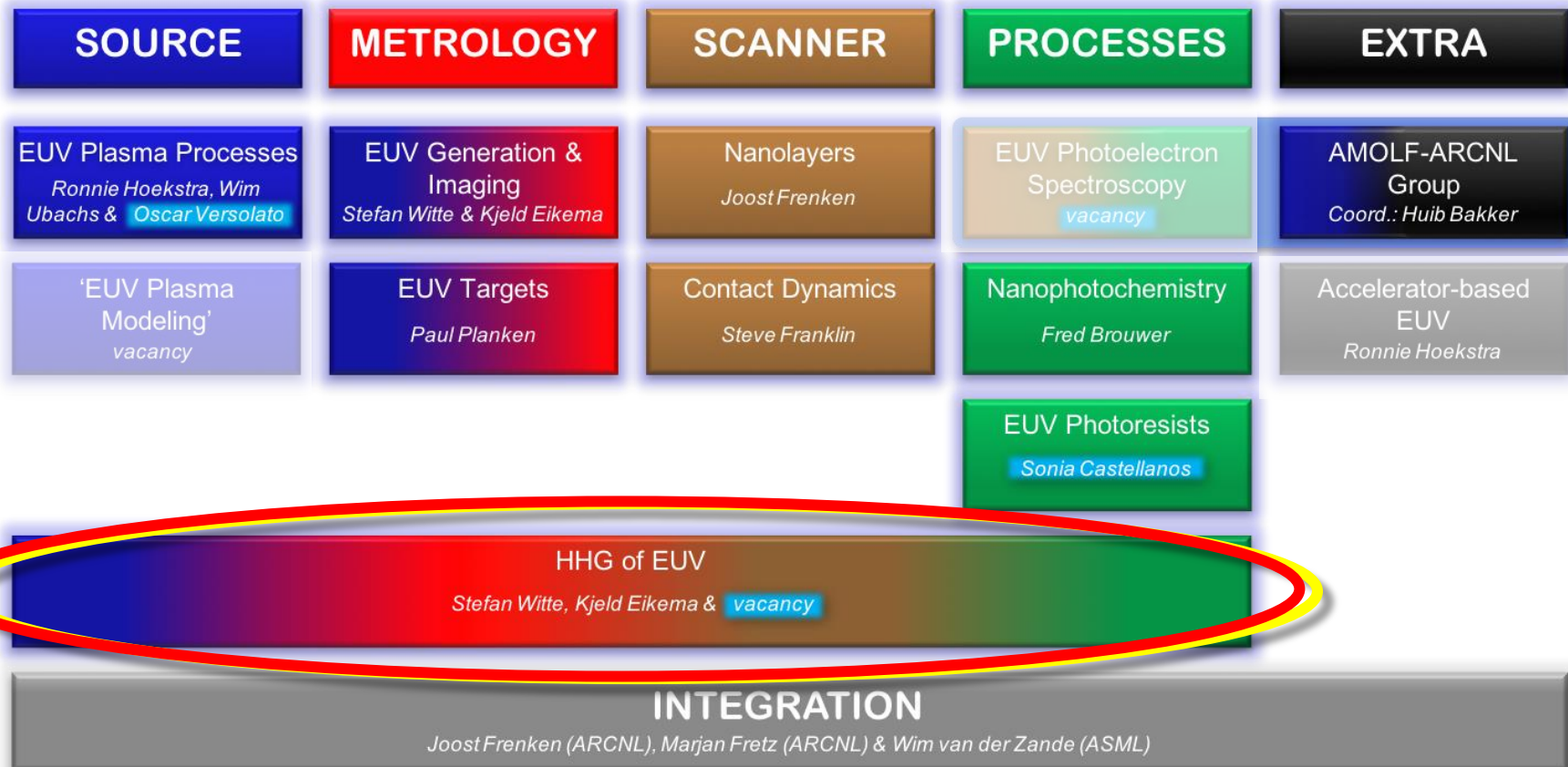
UNIVERSITEIT VAN AMSTERDAM



Provincie
Noord-Holland

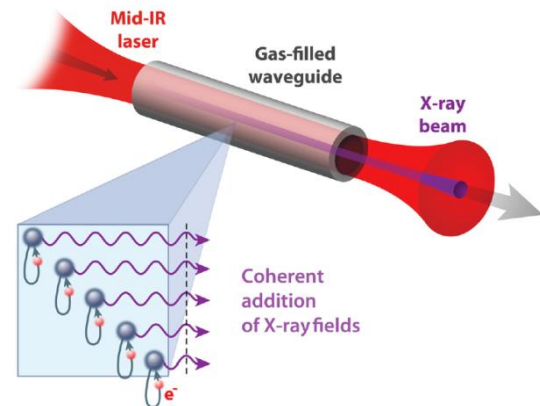
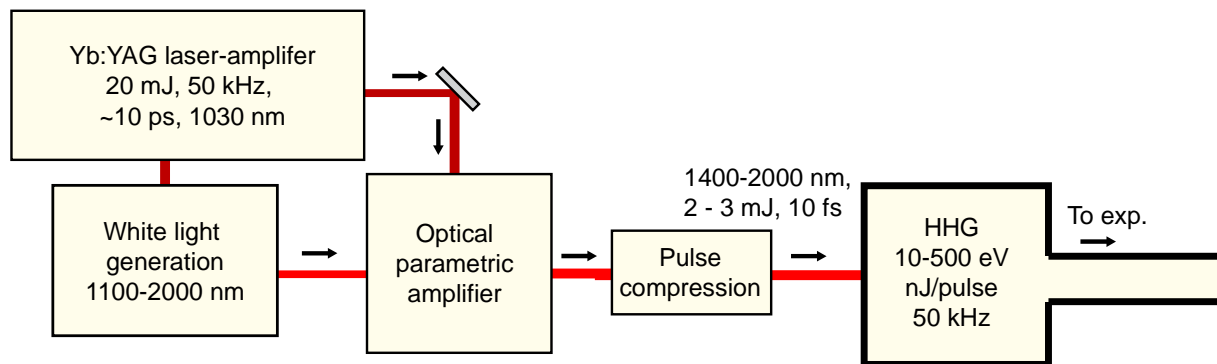


ARCNL's scientific program



The ARCNL Coherent Soft-X-ray Source

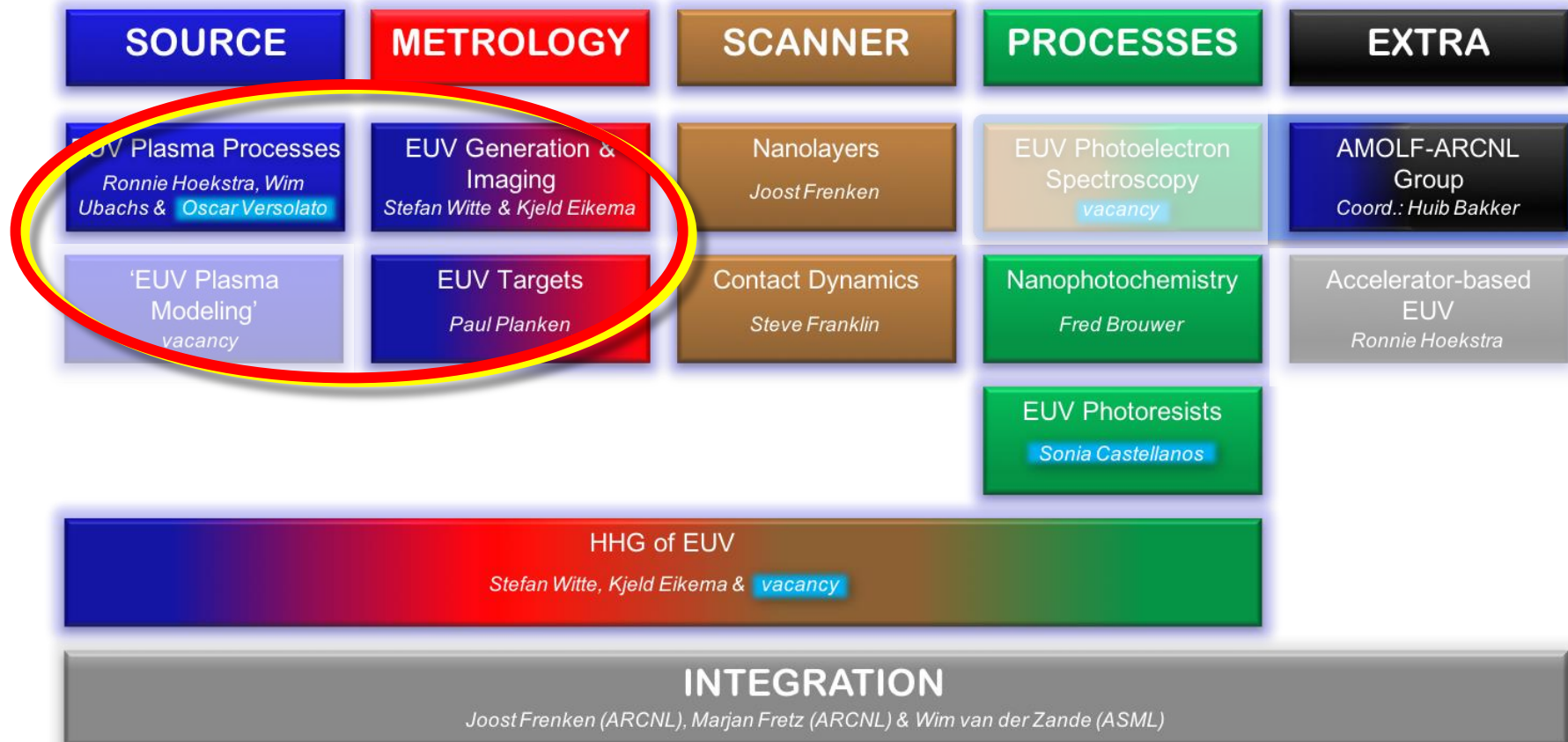
A high-flux EUV coherent EUV facility serving multiple ARCNL groups (imaging, photoresists, spectroscopy, etc.)



- New lab facilities ready and equipped.
- Pump laser based on Yb:YAG Innoslab amplifier technology (Amphos).
- Fully coherent beams of 10-500 eV (2-100 nm) radiation, up to mW-level average power.
- Output consists of sub-femtosecond soft-X-ray pulses, fully synchronized to the drive laser.

**Postdoc position
available now!**

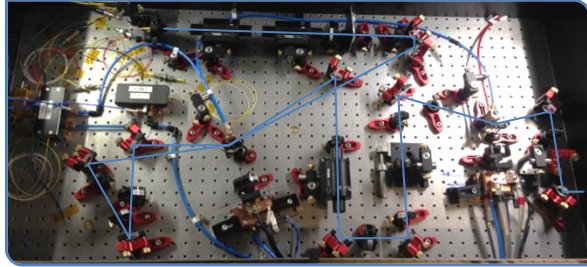
ARCNL's scientific program



Advanced 1064 nm lasers at ARCNL

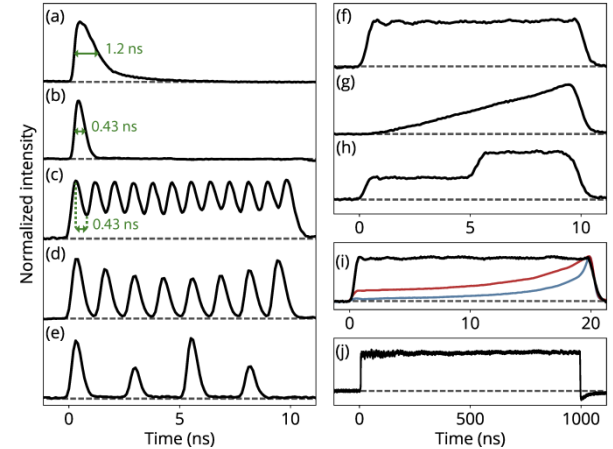
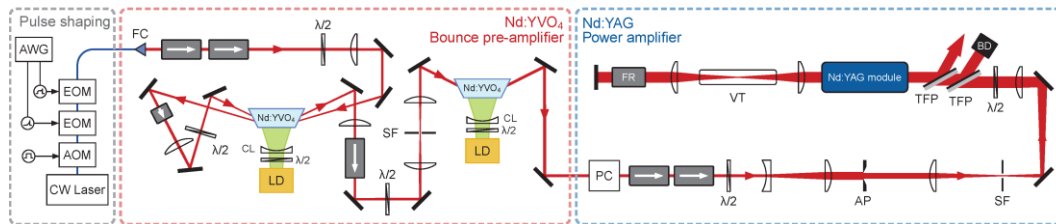
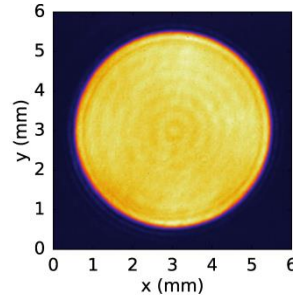
Picosecond laser system

- Pulse duration 15-110 ps
- Up to 200 mJ/pulse @ 100 Hz



Nanosecond laser system

- Pulse duration 0.4 – 1000 ns
- Arbitrary pulse shapes
- Up to 437 mJ/pulse @ 100 Hz

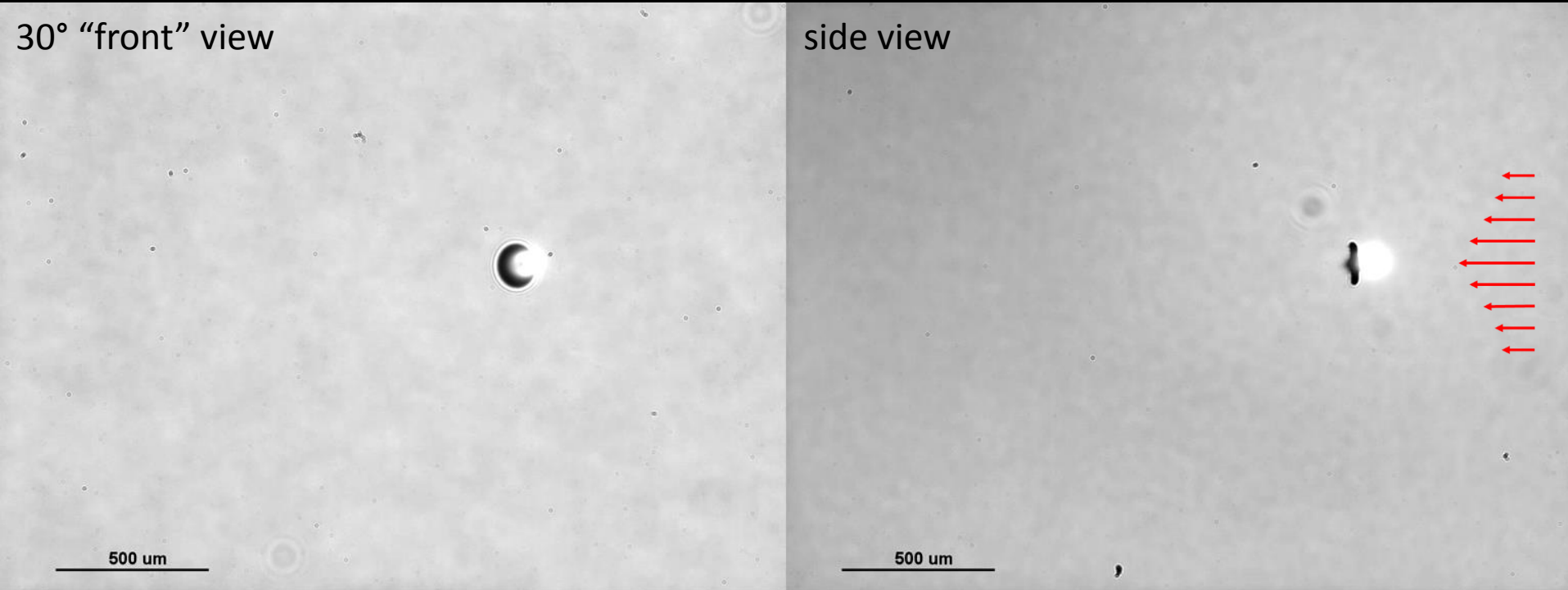
R.A. Meijer et al., Opt. Lett. **42**, 2758 (2017)

Femtosecond OPCPA (50 fs – 20 ps, 20 mJ/pulse) under construction

l: nanosecond prepulse

ns-pulse-driven droplet propulsion

Sensitive probe for plasma pressure scaling



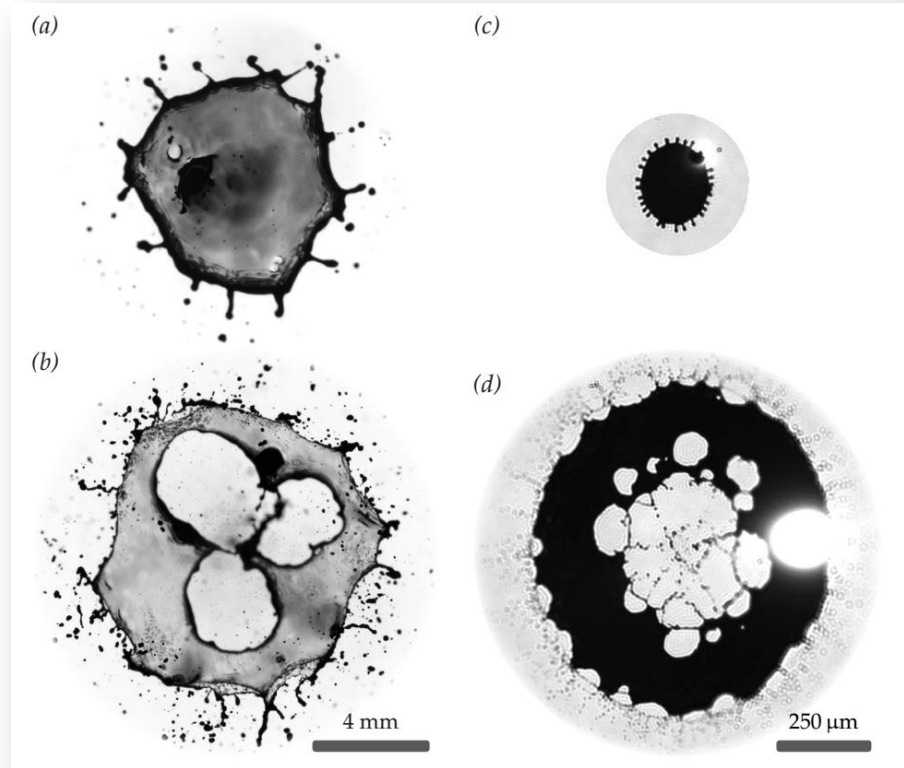
EUV Plasma Dynamics / Atomic Plasma Processes
EUV Generation & Imaging



A. Klein et al, *in preparation*; A. Klein et al, Phys. Rev. Appl. **4**, 044018 (2015);
H. Gelderblom, JFM **794**, 676 (2016), D. Kurilovich et al, Phys. Rev. Appl. **6**, 014018 (2016); D. Kurilovich et al, arXiv:1710.11426

ligamentation and hole formation

Correspondences mm-sized water and μm -sized tin drops



A. Klein et al, *in preparation*; A. Klein et al, Phys. Rev. Appl. **4**, 044018 (2015);

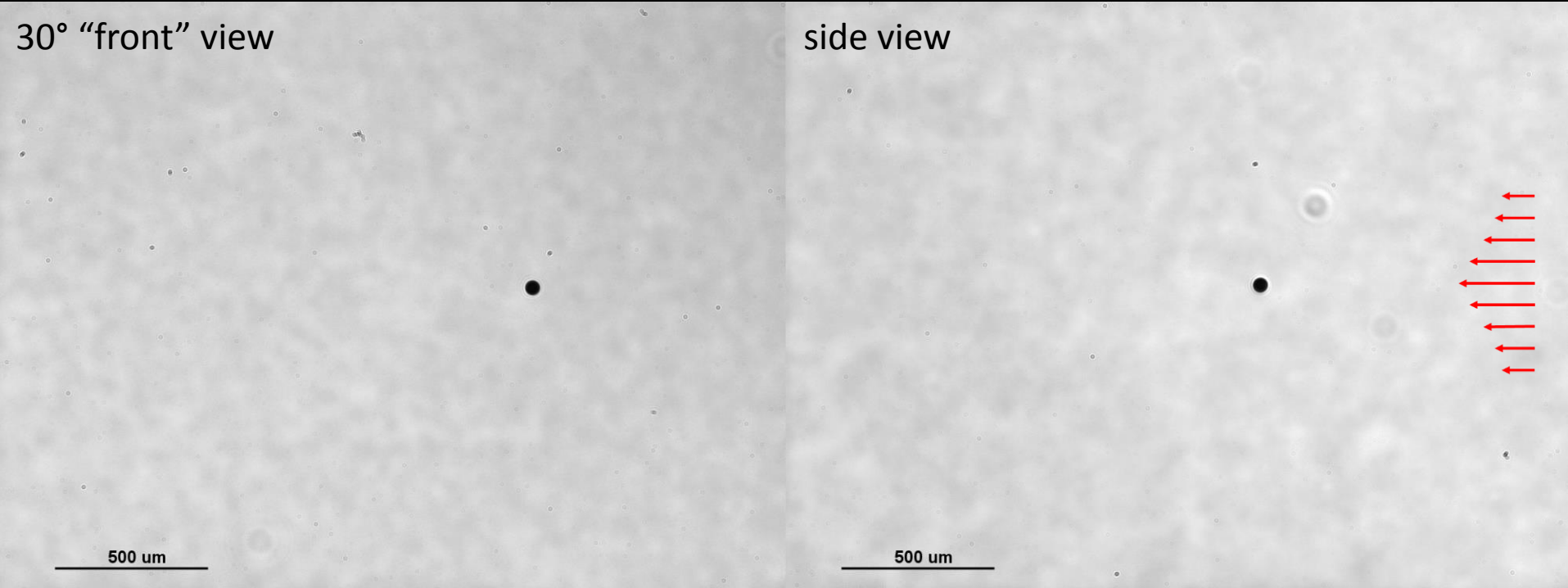
H. Gelderblom, JFM **794**, 676 (2016), D. Kurilovich et al, Phys. Rev. Appl. **6**, 014018 (2016); D. Kurilovich et al, arXiv:1710.11426

II: picosecond prepulse

Poster S44 by
D. Kurilovich

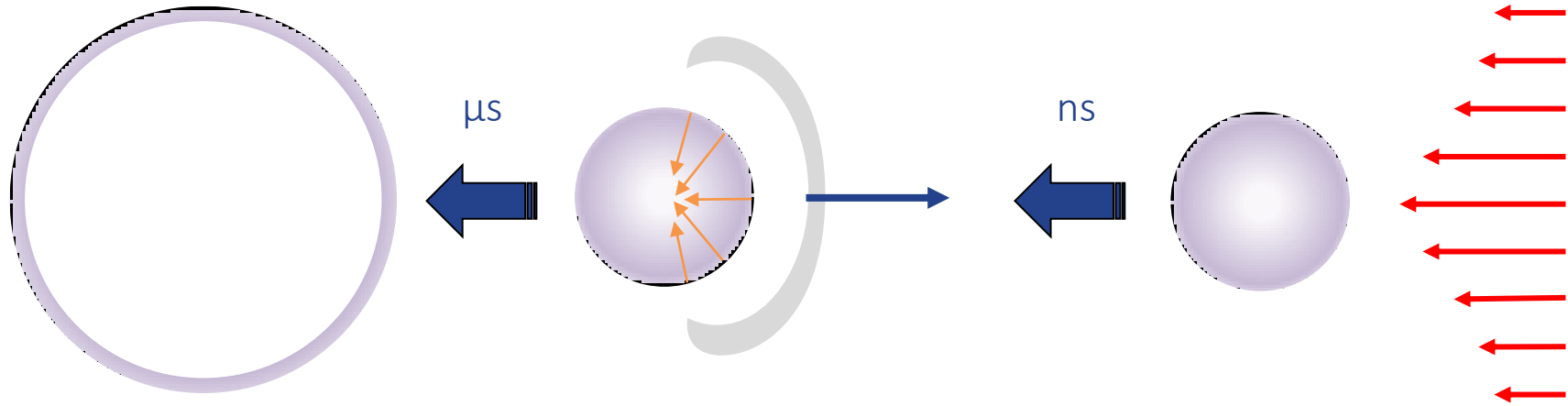
ps-pulse-driven droplet expansion

Cavitation and spallation from shockwaves



ps-pulse-driven droplet expansion

Cavitation and spallation from shockwaves

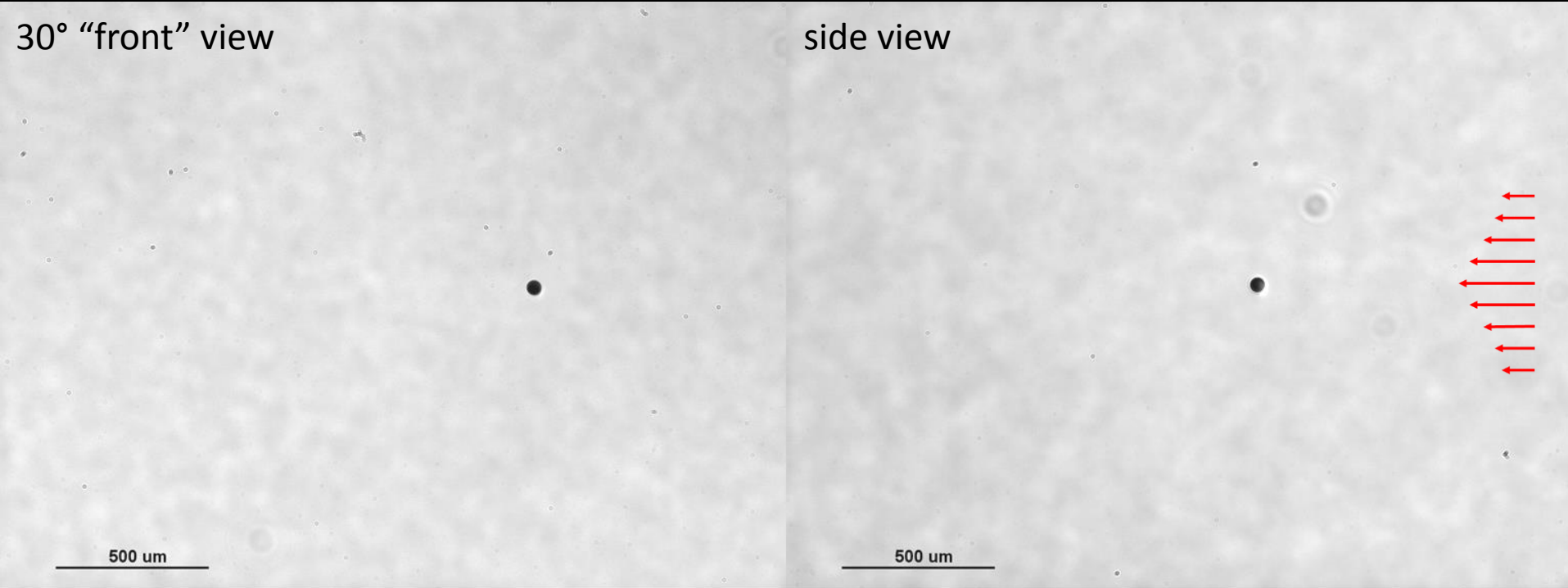


ps-pulse-driven droplet expansion

Cavitation and spallation from shockwaves

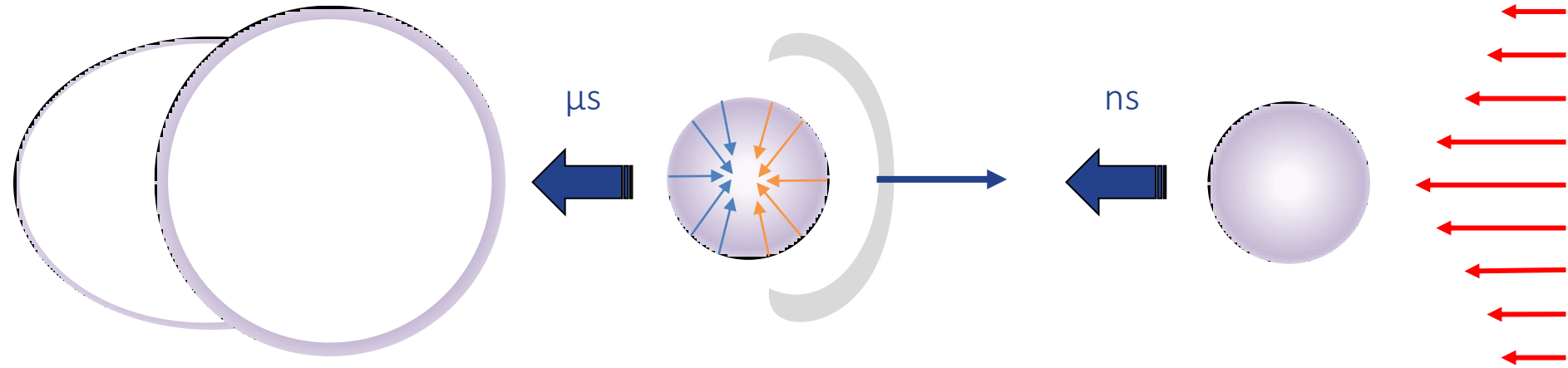
30° “front” view

side view



ps-pulse-driven droplet expansion

Cavitation and spallation from shockwaves

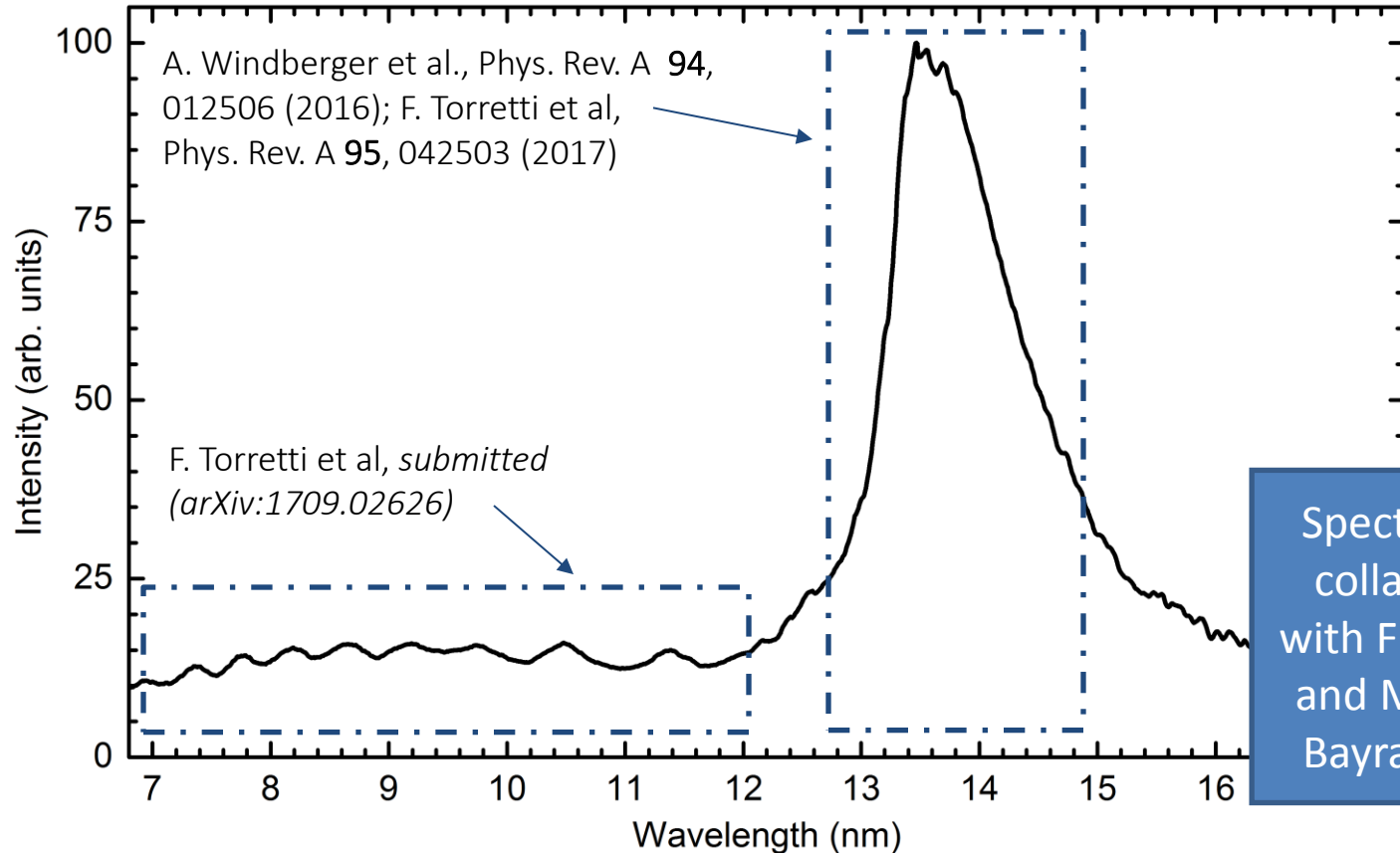


A. Y. Vinokhodov et al, Quant. Electr. **46**, 23 (2016)
M. M. Basko et al, Laser Phys. Lett. **14**, 036001 (2017)
M. Krivokorytov et al, Phys. Rev. E **95**, 031101 (2017)

III: spectroscopy

Nd:YAG-driven LPP EUV spectrum

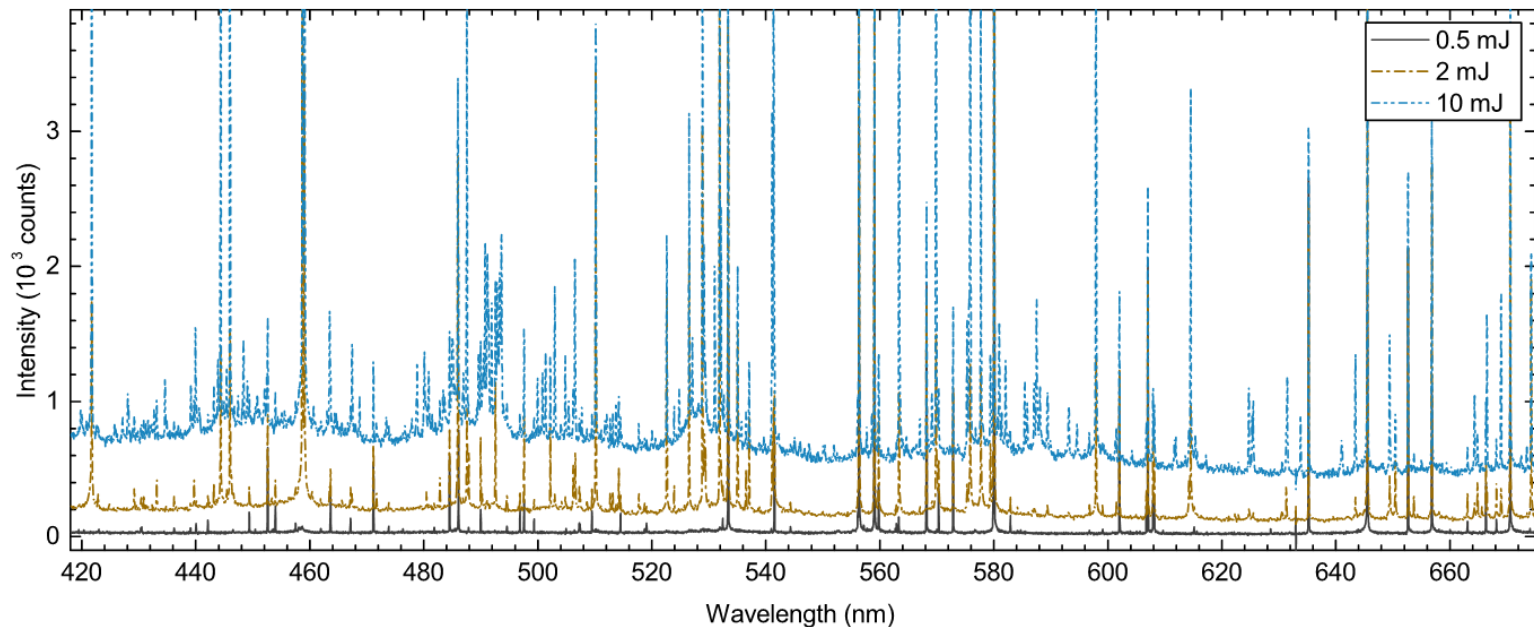
Unravelling atomic contributions



Spectrometer-
collaboration
with Fred Bijkerk
and Muharrem
Bayraktar (UT)

Nd:YAG-driven LPP optical spectrum

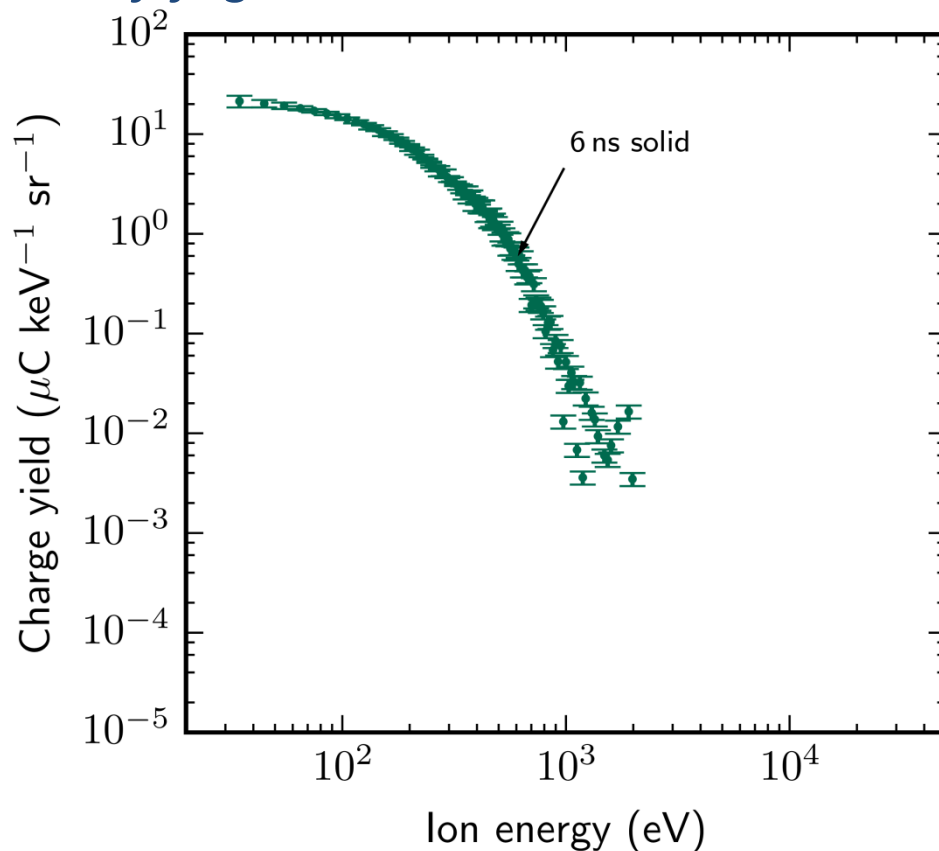
Unravelling atomic contributions (new line identifications)



IV: ion kinetic energy distributions

Nd:YAG-driven LPP ion energy spectrum

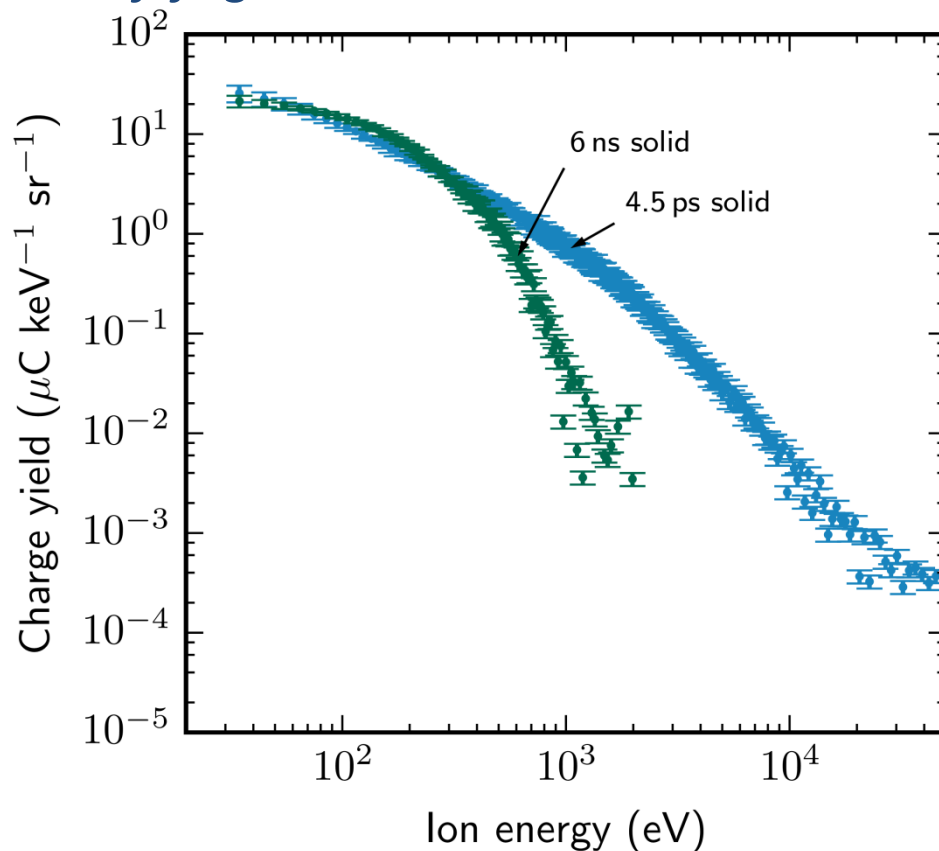
Faraday cup time-of-flight measurements



On arXiv by
noon tomorrow!

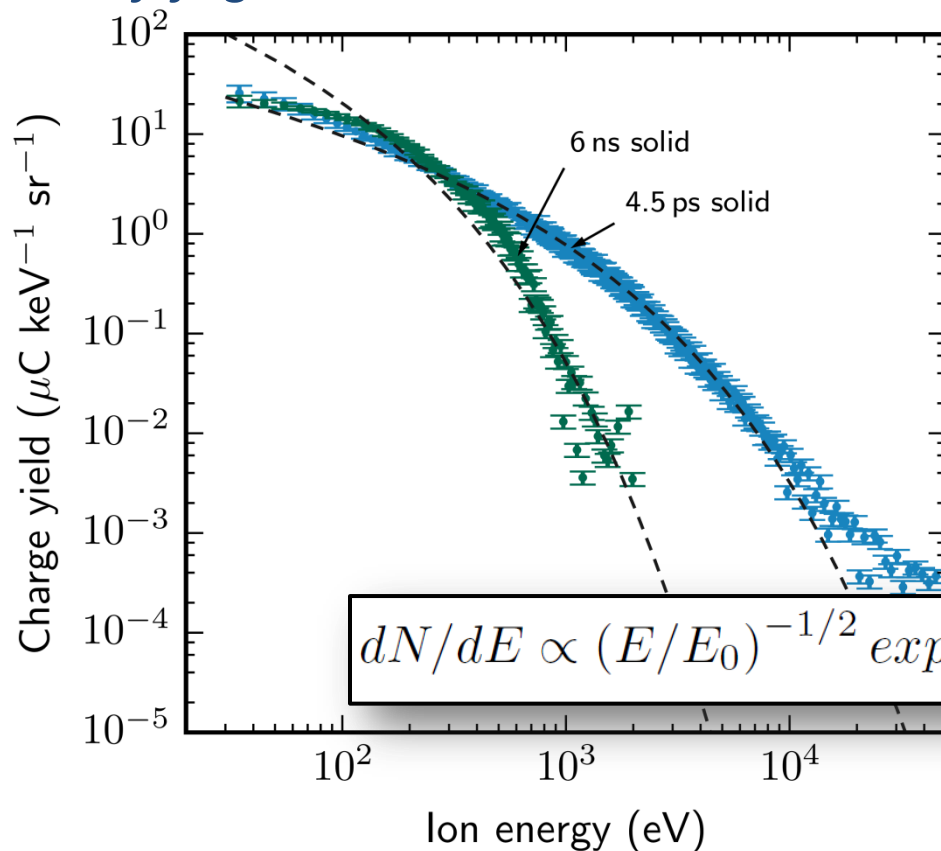
Nd:YAG-driven LPP ion energy spectrum

Faraday cup time-of-flight measurements



Nd:YAG-driven LPP ion energy spectrum

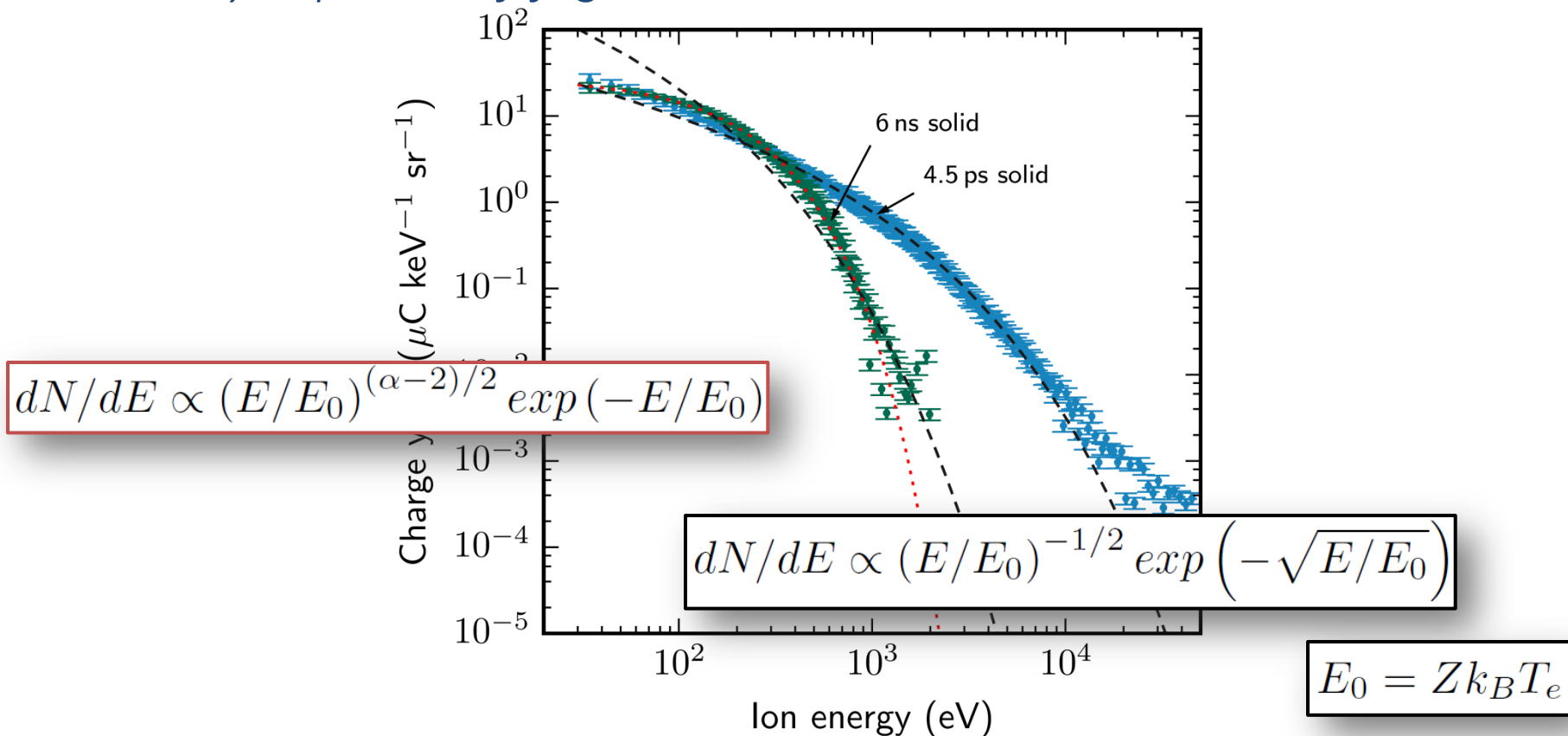
Faraday cup time-of-flight measurements



$$E_0 = Zk_B T_e$$

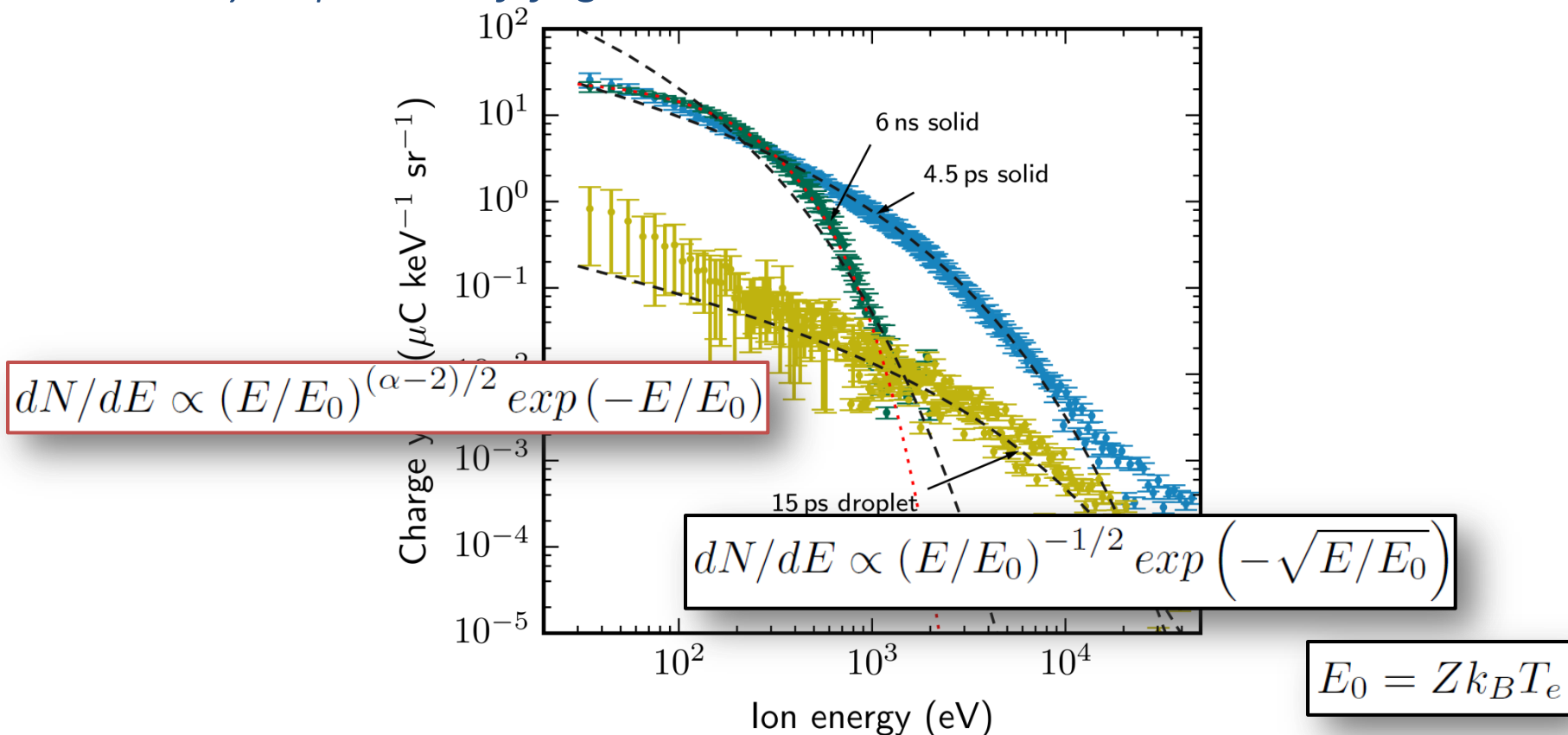
Nd:YAG-driven LPP ion energy spectrum

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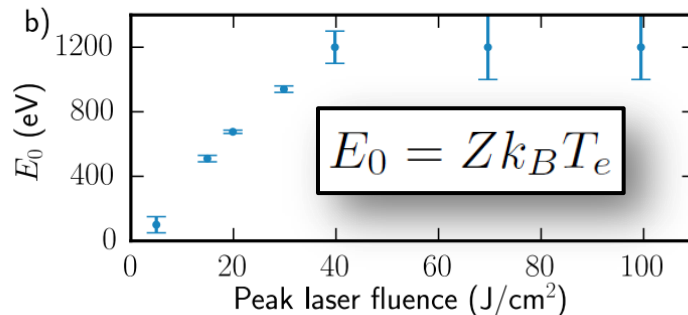
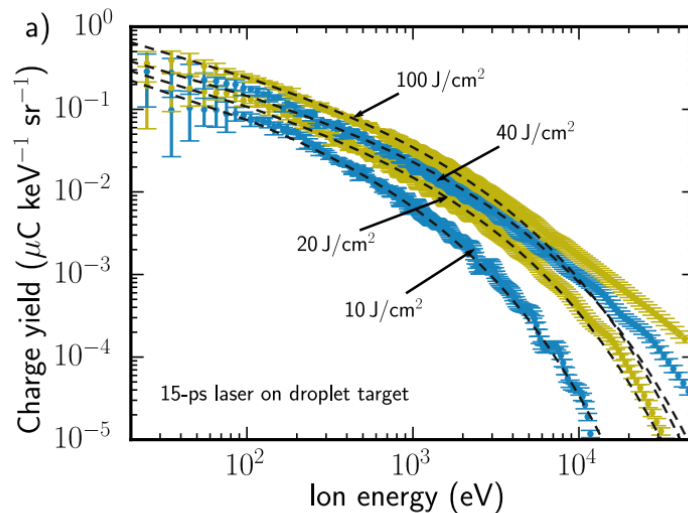
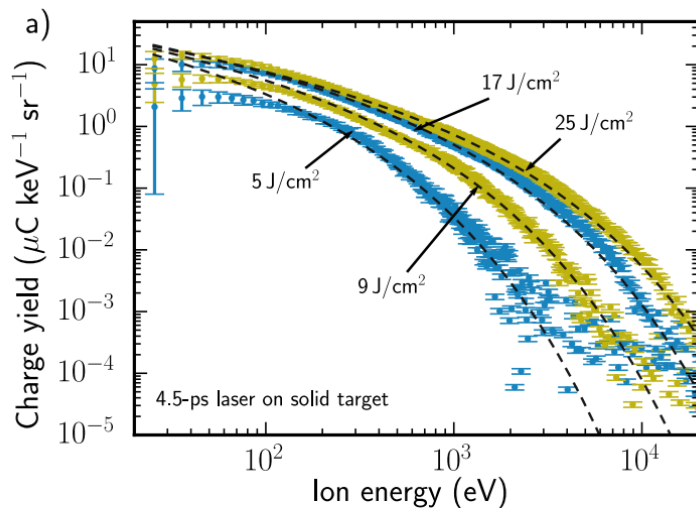
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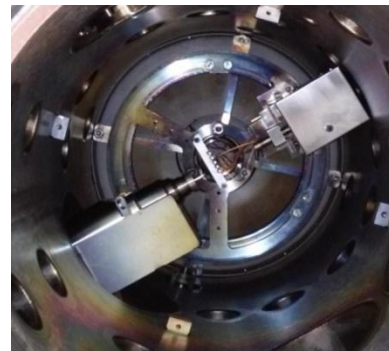
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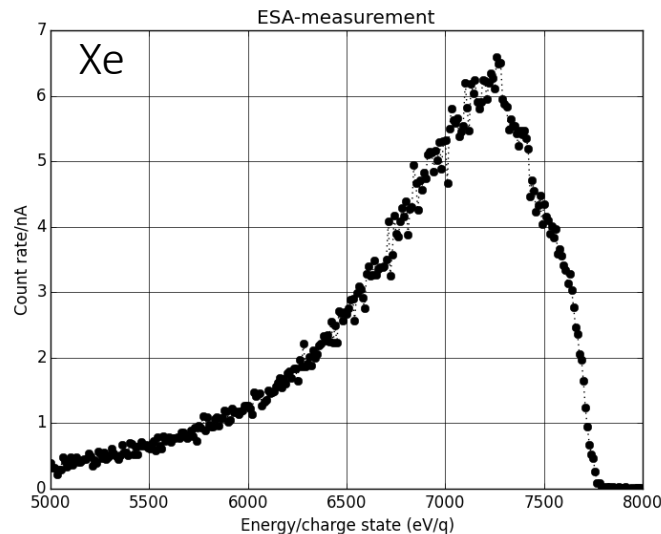
Research at ZERNIKELEIF@Groningen

Sn ions stopping, sputtering, and implantation



E_{beams} : (1-30)q keV ions

20 sept 2017: first 8q kV Sn¹⁺...Sn³⁺ beams extracted and transported to ion-surface set up, which can be floated on high voltage for low energy ion experiments



Research team

ARCNL EUV PP team:

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Joris Scheers (PhD)
Ruben Schupp (PhD)
Mart Johan Deuzeman (PhD)
N.N.
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Alex Bayerle (postdoc)
Laurens van Buuren (technician)
Ronnie Hoekstra (group leader)
Wim Ubachs (group leader)
Oscar Versolato (group leader)



ARCNL is a public-private partnership between FOM, UvA, VU and ASML

ARCNL EUV G&I team:

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Aneta Stodolna (postdoc)
Stefan Witte (group leader)
Kjeld Eikema (group leader)

ASML team

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Konstantin Tsigutkin
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Wim van der Zande
Jayson Stewart
Andrew Laforge
Alex Schafgans
Rob Rafac
Igor Fomenkov ... a.o.

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H. Bekker (MPIK)
S. Dobrodey (MPIK)
A. Ryabtsev (ISAN)
M. Basko (KIAM, ISAN)
D. Kim (ISAN)
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E. Kahl (UNSW Australia)
Muharrem Bayraktar (University of Twente)
Fred Bijkerk (University of Twente)

